Dietary Nutrients

More than just Nourishment

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Nutrients and Cellular Function

All cellular functions are regulated by DNA sequences that code for a protein – commonly known as gene. Therefore, it will be appropriate to say in a broader sense that gene functions regulate cellular physiology at the molecular level. On the other hand, the regulation of gene functions is quite complex and is controlled at the level of transcription (synthesis and modifications of RNA based on DNA sequence contained in the cell), translation (synthesis and splicing of protein based on signals carried by RNA) and ultimately during the formation of functional protein.

Studies have shown that nutrients and hormones either act directly to influence transcription rates or act indirectly through specialized signaling pathways. Beyond this, it has also been shown that the nutrients also regulate pre- and post-transcriptional events in the cell.

Proteins, Amino Acids and Genetics

As transcription factors, proteins can bind to regions called promoters in a DNA sequence and can “switch on” or “off” the transcription of a particular gene. It has been demonstrated that mammals can detect the quantity and quality of dietary protein. A diet deficient in protein in even a single essential amino acid (AA) will be metabolized and used for energy purposes by the body.

At the cellular level, the low quality protein or diet deficient in protein is manifested as “AA deprivation” that activates what is called as the AA response (AAR). The AAR initiates a cascade of reactions that affect the expression of several target genes, ultimately resulting in stunted growth in children on low protein diet directly as well as children born to mothers on such diets.

Fatty Acids and Genetics

Recent studies have established the role of fatty acids as modulators of gene function, along with their role as energy components. Fatty acids can stimulate or inhibit DNA transcription in a cell. Cells can sense the identity and quantity of individual fatty acids. This leads to the regulation of various genes in a differential manner.

The length of carbon chain, degree of saturation or unsaturation of fatty acids (that is, the absence or presence of a double bond between carbons), and position of double bond as in omega-3, omega-6 and omega-9 position has profoundly different effects on the biological properties and their regulation of gene expression. For example, the 20-carbon polyunsaturated fatty acids (PUFA) in omega-6 and omega-3 positions (arachidonic acid and eicosapentaenoic acid, respectively) are entirely different in their actions; arachidonic acid promotes inflammatory responses in the body while eicosapentaenoic acid suppresses it.

Dietary supplementation of omega-3 PUFA can modulate omega-6:omega-3 PUFA ratios in the body and increased omega-3 PUFA can lead to increased brain hippocampal gene expression, neurite growth and consequently improved spatial learning and memory. Thus, the type of fat contained in the food can produce differential effects and it will be inappropriate to blame dietary fat in toto for all diet-related diseases.

The development of nutrigenomics is still in the formative stages and requires resources and efforts for generation of individual genetic information and deeper understanding of the role of nutrients.
The advancement of knowledge has lead to the development of nutrigenomics that applies genomics, transcriptomics and metabolomics to understand functional genomics and evolve personalized nutrition. Molecular nutrition has evolved from conventional nutrition, applying advanced molecular biology tools.

**Carbohydrates and Genetics**
Most carbohydrates contained in the diet are converted into glucose. Glucose response elements (DNA sequences) that can allow binding of transcription factors have been characterized in several genes (for example, pyruvate kinase, acetyl-coenzyme A carboxylase and S14 genes). However, the exact mechanism of glucose action is presently unknown.

**Vitamins, Minerals and Genetics**
Various vitamins, directly or through their metabolites can interact with responsive sequences in DNA and influence gene function. For example, the downstream metabolites of vitamin A and D can bind and activate similar nuclear receptors to regulate target genes. Besides this, they also modify chromatin dynamics to influence formation of transcription pre-initiation complex.

Folic acid, a vitamin belonging to the vitamin-B complex group, is found to affect nucleotide synthesis, cell proliferation, DNA repair, and genomic stability. Therefore, sufficient folic acid levels in diet are required to ensure broad range of biological functions that go beyond simple clinical symptoms shown by folic acid deficiency.

Various minerals such as zinc, iron and most importantly calcium are known to profoundly influence the gene function. Using a technique known as transcriptome profiling, it has been shown that deficiency of a single nutrient can affect gene function. For instance, deficiency of zinc alone can affect mRNA/protein levels of hundreds of genes.

Even the fibre contained in the diet can directly or directly influence cell function or gene function through its products of metabolism, mostly fatty acids or by modulating absorption of certain nutrients such as minerals from the intestine.

In a nutshell, nutrients in the diet play a major role in regulation of cellular functions.

**Nutrigenomics and Personalized Nutrition**
Several remarkable studies suggest that diet played a significant role in the physiological and phylogenetic evolution of mammals, especially humans. One of the recent advances, known as next generation sequencing technology, has made rapid DNA sequencing and understanding the codes contained therein in relation with the biological function possible. This has facilitated understanding of the role and influence of diet in the genome function, particularly giving insights into, something known as nutrigenomics.

Nutrigenomics studies the interaction between nutrition and genome including the precise role of nutrients in the regulation of metabolic pathways and malnutrition induced pathogenesis in relation with individual specific genotype. Dr. Jing X. Kang, a leading researcher in the field of nutrigenomics and lipid medicine at Massachusetts General Hospital and Harvard Medical School, suggests that development of integrated technologies and biomarkers for rapid and accurate assessment of an individual’s nutritional needs can be used in health interventions (Jing X. Kang. 2012. Identification of Metabolic Biomarkers for Personalized Nutrition, Journal of Nutrigenetics and Nutrigenomics, 5: 1-2).

The application of nutrigenomics and personalized nutrition is similar to the approach of personalized medicine -prescribing appropriate drug doses according to an individual’s genetic makeup for optimizing drug effects and prevent adverse reactions. Dr. Kang further emphasizes that the personalized nutrition may be even more critical than personalized medicine given that dietary intake is a fundamental part of everyday life that affects our health.

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